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# HEAT AMELIORATIVE EFFECTS OF RUMEN PROTECTED NIACIN SUPPLEMENTATION IN LACTATING SURTI BUFFALOES

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## ABSTRACT

Niacin may cause evaporative thermolysis through cutaneous hyperemia, vasodilation, increased sweating rate and decreased skin temperature. It is antilipolytic and can improve metabolic responses. Heat stress ameliorative effects of rumen protected niacin (RPN) supplementation in lactating Surti buffaloes during summer has been investigated in present study. Fourteen lactating Surti buffaloes were divided into two groups (Control-T1, N=7; RPN-T2, N=7). T2 (RPN) group was supplemented with RPN 6 g/ animal/ day in two divided dose for 4 weeks. Meteorological, physiological, sweating rate and skin temperature parameters, milk yield and composition were recorded at weekly intervals. Hematological and biochemical analytes were analyzed at week 1 and 4. RPN supplementation decreased physiological parameters RT, RR and TT; increased (P≤0.05) sweating rate and decreased (P≤0.05) skin surface temperature; increased (P≤0.05) TEC, Hb, HCT, LYM and decreased (P≤0.05) GRAN in hematological profile; increased (P≤0.05) glucose and decreased (P≤0.05) cholesterol, triglyceride, NEFA and BHB among biochemical metabolites and increased (P≤0.05) GSH and SOD and decreased (P≤0.05) LPO in oxidative stress profile. RPN supplementation increased milk yield and milk fat. It was concluded that supplementation of rumen protected niacin in lactating Surti buffaloes increases sweating rate, reduces oxidative stress and increases milk fat and milk production.

**Keywords***: Bubalus bubalis*, buffaloes, rumen protected niacin, Surti buffaloes, heat stress

## INTRODUCTION

High ambient temperature during summer causes increased core body temperature, altered hormonal profile and energy metabolism (Collier *et al*., 2008; Wheelock *et al*., 2010) that ultimately decreases milk production of cows. Heat ameliorative measures that can increase heat dissipation by transfer of heat from core to the surface and its evaporation from the surface may prevent decrease in milk production to certain extent. Niacin has been known to cause intense skin flushing (Gille *et al*., 2008), that may increase peripheral heat loss. Supplementation of 12 g/d

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of RPN increased sweating rates, reduced body temperatures and vaginal temperatures of lactating dairy cows exposed to heat stress (Zimbelman *et al*., 2010; Zimbelman *et al*., 2013). Niacin supplementation in cows during early lactation also improves 3 to 4% milk production (Niehoff *et al*., 2008).

Niacin is a vitamin that supplies coenzymes (NAD, NADP) for redox reactions. Niacin is antilipolytic and decreases negative energy balance by decreasing non-esterified fatty acid (NEFA) levels (Pires and Grummer, 2007) and β-OH butyrate (Al-Abbasy, 2013). Increased plasma NEFA concentration has been associated with insulin resistance in Holstein cows. Reduction of plasma NEFA concentration by nicotinic acid increases response to insulin in feed-restricted Holstein cows (Pires *et al*., 2007). Niacin increases vasodilation and may increase sweating rate. Meager amount of niacin is synthesized by rumen microbes. Niacin supplemented orally is degraded in rumen and has low postruminal bioavailability as well as blood levels. Raw niacin used in earlier studies for evaluating effects on heat stress was largely metabolized by rumen microbes and only 3 to 10% of it escaped ruminal degradation (Santschi *et al*., 2005). Therefore, large doses of niacin were supplemented in earlier studies. Encapsulation increases its delivery to small intestine (Yuan *et al*., 2012) and its bioavailability.

Hence with the hypothesis that rumen protected niacin has higher bioavailability, and therefore may increase sweating rate via increased vasodilation and help in reducing core body temperature during summer, present study was conducted with the objective to know heat ameliorative effects of rumen protected niacin supplementation on sweating rate, biochemical analytes, and production performance in lactating Surti buffaloes during summer season.

## MATERIALS AND METHODS

Present study (approved by Institutional Animal Ethics Committee) was conducted on 14 lactating Surti buffaloes maintained at Livestock Research Station of university from mid-May, 2020 to mid-June, 2020. Selected buffaloes with previous year lactation yield (1001.37±44.44 Kg), parity (2.64±0.32) and stage of lactation (153.29±11.10 Days PP) were randomly divided equally into two groups i.e., T1 (Control, N=7) and T2 (Rumen Protected Niacin, RPN, N=7). T2 buffaloes were fed 6 g RPN/animal/day in divided dose morning and evening for 4 weeks. Availability of RPN was 65% i.e., 3.9 g. Meteorological variations i.e., ambient temperature and relative humidity of the experimental shed were recorded using temperature-humidity datalogger. Temperature humidity Index (THI) was calculated using formula THI=(1.8×T+32)-[(0.55-0.0055×RH)×(1.8×T-26)] given by Tucker *et al*. (2008) [T'-ambient temperature ($^{o}$C);'RH'-relative humidity(%)]. Physiological parameters i.e., rectal temperature (RT), respiration rate (RR) and tympanic temperature (TT) as well as skin temperature and sweating rate were recorded during at 9.00 am and 3.00 pm at weekly intervals. Sweating rate was determined as per Schleger and Turner (1965) that is based on using chromatography paper discs impregnated with $CoCl_2$. Formula used for calculation of sweating rate was Sweating rate (g/$m^2$hr) = (22x3600)/2.06t ['t' is time (in seconds) for change in color of impregnated $CoCl_2$ discs]. Blood samples with anticoagulant $K_3$EDTA and without anticoagulant were collected at start and end of study.

Whole blood was used to determine hematological parameters such as total erythrocyte count (TEC), hematocrit (HCT), hemoglobin (Hb), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red cell distribution width (RDW), total leukocyte count (TLC), lymphocyte (LYM), mid-sized cells (MID), granulocyte (GRAN), total platelet count (PLT) and mean platelet volume (MPV) using automated hematology cell counter (MEDONIC CA 620/530 VET). Whole blood was used for analysis of GSH (Moron *et al*., 1979), SOD (Madesh and Balasubramanian, 1998) and LPO (Rehman, 1984). Plasma was used for analysis of NEFA using method described by Shipe *et al*. (1980) with slight modifications. Serum was used for analysis of biochemical metabolites such as glucose, total cholesterol, triglyceride and β-hydroxy butyrate (BHB) using standard kits/protocols (Randox kits). Weekly milk yield and changes in milk composition were recorded during the period of study. Dry matter intake was determined at beginning and end of study. Results obtained were analyzed using student t test and significant difference was considered at 5% level (Snedecor and Cochran, 1994).

## RESULTS AND DISCUSSIONS

### Microclimatic conditions and physiological parameters

Throughout study, ambient temperature and THI in afternoon were significantly (P≤0.05) higher than morning (Table 1). Amongst physiological parameters as shown in Table 2, afternoon RT, TT and RR in 2nd, 3rd and 4th week were significantly (P≤0.05) lower in buffaloes of T2 (RPN) group than T1 (Control). Lowering of these crucial vital parameters indicated amelioration of heat stress due to RPN supplementation. Findings of present study corroborated with 0.5°C decrease in vaginal temperature, increased RT in afternoon and RR in heat stress cows (Zimbelman *et al*., 2010) on feeding of RPN 12 g/animal/day.

### Skin temperature and sweating rate

In T2 (RPN) group in both shaved and unshaved area of rump and shoulders from 2nd week onwards sweating rate (Table 4) significantly (P≤0.05) increased and skin temperature as shown in (Table 3) significantly (P≤0.05) decreased in afternoon. Niacin has been associated with increased cutaneous vasodilation that is mediated by production of prostaglandin D by epidermal Langerhans cells (Benyó *et al*., 2006; Maciejewski-Lenoir *et al*., 2006). Increased cutaneous vasodilation and increased skin blood flow causes increased sweating rate in humans (Welch *et al*., 2009). Evaporation of sweat results in heat loss from skin surface thereby lowering its temperature. In consensus with this mechanism the findings of the present study also indicates that RPN supplemented buffaloes lost heat from the skin surface by increasing sweating rate. Heat loss by increasing sweating rate due to niacin has also been reported (Zimbelman *et al*., 2010).

### Hematological parameters

At the end of study i.e., week 4, erythrocytic parameters in hematological profile (Table 5) of TEC, HCT and Hb were significantly (P≤0.05) higher in T2 (RPN) group as compared to T1 (Control). Similarly at week 4 among leukocytic parameters LYM% was significantly (P≤0.05) higher and GRAN% was significantly (P≤0.05) lower in T2 (RPN) group as compared

to T1 (Control). Heat stress has been implicated to lower Hb concentration and TEC in cattle (Berian *et al*., 2019). Findings of present study implicate direct stimulatory effect of niacin on erythrocytic parameters as well as indirect effect of its heat stress ameliorative action. Heat stress has been found to both decrease (Bhan *et al*., 2012) and increase leukocytes (Seixas *et al*., 2014). However, in the present study TLC was only slightly higher in RPN group. Since lymphocytes decrease (Van Eerd, 2019; Devaraj and Upadhyay, 2007) and neutrophils increase (Chaudhary *et al*., 2020) due to heat stress, it is likely that RPN supplementation mitigates adverse impact of heat stress resulting in higher lymphocytes and lower neutrophils as compared to control.

**Biochemical parameters**

Analysis of blood biochemical parameters as shown in Table 6 revealed that in RPN group (T2) at week 4, significantly (P≤0.05) higher glucose levels and significantly (P≤0.05) lower cholesterol, triglyceride, NEFA and BHB levels were present as compared to Control group (T1). Increase in blood glucose concentration and decrease in total cholesterol, triglycerides and NEFA shows that RPN supplementation improves lipid profile and stimulates process of gluconeogenesis. Decrease in NEFA levels may also improve response to insulin. Decrease in NEFA on 7- and 14-days pp has been observed in RPN supplemented cows by Yuan *et al.* (2012). Niacin inhibits lipolysis and therefore decreases NEFA concentration (Carlson, 2005). Concentration of triglyceride is also related to NEFA since decrease in NEFA level is associated with prevention of accumulation of triglyceride. Niacin supplementation in early lactating cows may decrease rate of fat mobilization and concentration of ketones in blood along with increase in level of blood glucose. Niacin supplementation may enhance propionate concentration and diminish butyrate concentration in rumen liquor. It has been reported that feeding 6g/niacin/head/day during last two weeks of gestation and in early lactation increases the blood glucose concentration and rate of fat metabolism that in turn prevents synthesis of ketone bodies (Panda *et al*., 2017).

Antioxidants GSH and SOD significantly (P≤0.05) increased while LPO significantly (P≤0.05) decreased in T2 (RPN) group. These findings correspond to reduction of oxidative stress due to RPN supplementation. GSH and SOD are important antioxidants that protect cells from oxidative stress. It may be reasoned that niacin may possess antioxidant potential as it improves the lipid profile and might prevent peroxide formation.

**Dry matter intake**

Dry matter intake per animal in T1 (Control) and T2 (RPN) was 11.89 kg and 11.84 kg at beginning and was 11.06 and 11.69 kg at end of study respectively. Niacin has otherwise not been associated with any effect on dry matter intake (Zimbelman *et al*., 2013). This indicates that metabolic effects of niacin may not be due to changes in dry matter intake of the animal.

**Milk production and composition**

Milk components (Table 7) showed significant (P≤0.05) increase in fat%, lactose%, SNF%, density% and protein% at week 3 and 4 in T2 (RPN) group. Overall milk yield (Table 8) was significantly (P≤0.05) higher for T2 (RPN) group than T1 (Control). Similarly, Zimbelman *et al*. (2013) have also found increase in milk yield in lactating dairy cows that were fed RPN but this increase was only observed at higher THI and heat stress. Their results were also suggestive that

Table 1. Microclimatic conditions of Shed (Mean±SE).

| Weeks | Morning (6 am-9 am) | Afternoon (12 pm-3 pm) | Day (7 am-6 pm) | Night (7 pm -6 am) |
|---|---|---|---|---|
| **Ambient temperature (°C)** | | | | |
| W1 | 30.99$^{b}$±0.31 | 37.08$^{a}$±0.90 | 34.91$^{a}$±0.65 | 28.99$^{b}$±0.16 |
| W2 | 30.35$^{b}$±0.43 | 36.73$^{a}$±0.61 | 34.19$^{a}$±0.51 | 29.59$^{b}$±0.27 |
| W3 | 28.77$^{b}$±0.43 | 34.48$^{a}$±0.25 | 32.56$^{a}$±0.32 | 26.23$^{b}$±0.20 |
| W4 | 26.93$^{b}$±0.69 | 32.87$^{a}$±0.28 | 30.62$^{a}$±0.45 | 25.38$^{b}$±0.19 |
| **RH (%)** | | | | |
| W1 | 72.12$^{a}$±1.15 | 56.53$^{b}$±3.52 | 60.88$^{b}$±2.04 | 76.89$^{a}$±0.65 |
| W2 | 74.15$^{a}$±1.77 | 52.50$^{b}$±1.63 | 60.80$^{b}$±1.53 | 74.42$^{a}$±0.36 |
| W3 | 82.03$^{a}$±2.01 | 63.91$^{b}$±1.67 | 69.13$^{b}$±1.53 | 82.78$^{a}$±0.74 |
| W4 | 80.50$^{a}$±1.37 | 61.82$^{b}$±2.57 | 68.09$^{b}$±1.11 | 82.24$^{a}$±1.31 |
| THI | | | | |
| W1 | 83.03$^{b}$±0.48 | 88.84$^{a}$±0.69 | 86.69$^{a}$±0.53 | 80.79$^{b}$±0.29 |
| W2 | 82.47$^{b}$±0.43 | 87.60$^{a}$±0.68 | 85.64$^{a}$±0.56 | 81.39$^{b}$±0.42 |
| W3 | 81.04$^{b}$±0.48 | 86.89$^{a}$±0.14 | 84.89$^{a}$±0.26 | 77.16$^{b}$±0.34 |
| W4 | 77.96$^{b}$±1.17 | 84.22$^{a}$±0.67 | 81.83$^{a}$±0.66 | 75.75$^{b}$±0.42 |

Means bearing different superscripts (a, b) across rows differ significantly (P≤0.05) between morning and afternoon, day and night.

Table 2. Changes in physiological parameters (Mean±SE) on supplementation of rumen protected niacin in Surti buffaloes.

| Weeks | Rectal temperature (°F) | | Tympanic temperature (°F) | | Respiration rate (/min) | |
|---|---|---|---|---|---|---|
| | Morning | | | | | |
| | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 Control) | T2 (RPN) |
| W1 | 100.69±0.13 | 100.67±0.13 | 101.07±0.10 | 101.13±0.13 | 21.71±1.02 | 22.00±1.07 |
| W2 | 100.74±0.12 | 100.63 ±0.11 | 101.14 ±0.10 | 101.11 ±0.15 | 24.29 ±1.19 | 22.57 ±1.94 |
| W3 | 100.66 ±0.08 | 100.57 ±0.13 | 101.36 ±0.06 | 101.16 ±0.11 | 26.00 ±1.85 | 23.14 ±1.30 |
| W4 | 100.54 ±0.08 | 100.43 ±0.10 | 101.39 ±0.12 | 101.30 ±0.10 | 24.57 ±1.49 | 23.71 ±1.34 |
| Afternoon | | | | | | |
| W1 | 101.76±0.10 | 101.44±0.15 | 102.60±0.09 | 102.69±0.10 | 32.29±0.81 | 30.29±0.92 |
| W2 | $101.71^{a}$±0.07 | $101.27^{b}$±0.07 | $102.59^{a}$±0.13 | $102.19^{b}$±0.08 | $37.43^{a}$±1.43 | $28.29^{b}$±2.33 |
| W3 | $101.40^{a}$±0.09 | $101.23^{b}$±0.09 | $102.44^{a}$±0.13 | $102.06^{b}$±0.14 | $39.14^{a}$±1.30 | $30.57^{b}$±2.75 |
| W4 | $101.54^{a}$±0.09 | $101.19^{b}$±0.11 | $102.54^{a}$±0.06 | $102.21^{b}$±0.11 | $39.14^{a}$±1.30 | $29.14^{b}$±1.50 |

Means bearing different superscripts (a, b); across rows differ significantly (P≤0.05); between T1 (Control-N=7) and T2 (RPN-N=7).

Table 3. Changes in skin temperature (Mean±SE) (°C) of different body regions on supplementation of rumen protected niacin in Surti buffaloes.

| Weeks | Rump (Unshaved) | | Rump (Shaved) | | Shoulder region (Unshaved) | | Shoulder region (Shaved) | |
|---|---|---|---|---|---|---|---|---|
| | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) |
| **Morning** | | | | | | | | |
| W1 | 34.66±0.13 | 34.63±0.12 | 34.17±0.08 | 34.23±0.09 | 35.33±0.24 | 35.30±0.22 | 34.74±0.13 | 34.80±0.20 |
| W2 | 35.43±0.24 | 35.31±0.13 | 34.74±0.13 | 34.71±0.10 | 36.00±0.35 | 35.89±0.23 | 36.10±0.35 | 35.99±0.23 |
| W3 | 34.83±0.27 | 34.77±0.15 | 34.14±0.20 | 34.17±0.15 | 36.11±0.19 | 35.17±0.16 | 35.13±0.14 | 34.89±0.08 |
| W4 | 34.63±0.33 | 34.66±0.20 | 34.11±0.28 | 34.26±0.23 | 35.43±0.57 | 35.26±0.41 | 35.53±0.57 | 35.36±0.41 |
| **Afternoon** | | | | | | | | |
| W1 | 36.23±0.24 | 36.11±0.13 | 36.34±0.13 | 36.31±0.10 | 36.40±0.35 | 36.29±0.23 | 35.54±0.13 | 35.60±0.20 |
| W2 | $37.33^{a}$±0.27 | $36.27^{b}$±0.15 | $36.24^{a}$±0.13 | $35.21^{b}$±0.10 | $37.40^{a}$±0.39 | $36.34^{b}$±0.26 | $36.90^{a}$±0.21 | $36.03^{b}$±0.20 |
| W3 | $36.16^{a}$±0.29 | $35.23^{b}$±0.21 | $35.76^{a}$±0.09 | $35.10^{b}$±0.08 | $37.13^{a}$±0.31 | $35.40^{b}$±0.13 | 36.69±0.38 | 35.90±0.30 |
| W4 | $36.19^{a}$±0.18 | $35.30^{b}$±0.13 | $35.69^{a}$±0.08 | $34.94^{b}$±0.16 | $36.66^{a}$±0.17 | $35.34^{b}$±0.12 | $36.26^{a}$±0.15 | $35.01^{b}$±0.11 |

Means bearing different superscripts (a, b); across rows differ significantly (P≤0.05); between T1 (Control- N=7) and T2 (RPN-N=7).

Table 4. Changes in sweating rate (Mean±SE) (g/m$^2$.hr) of different body regions on supplementation of rumen protected niacin in Surti buffaloes.

| Weeks | Rump (Unshaved) | | Rump (Shaved) | | Shoulder region (Unshaved) | | Shoulder region (Shaved) | |
|---|---|---|---|---|---|---|---|---|
| | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) |
| **Morning** | | | | | | | | |
| W1 | 69.93±2.20 | 70.51±3.29 | 75.86±1.60 | 77.16±3.53 | 68.77±3.29 | 67.13±3.83 | 72.81±3.15 | 75.69±3.12 |
| W2 | 69.30±2.06 | 71.83±2.40 | 74.83±2.80 | 77.10±3.04 | 60.84±1.41 | 65.65±2.89 | 67.68±1.26 | 71.73±2.44 |
| W3 | 67.14±1.61 | 73.19±2.13 | 72.47±1.10 | 77.19±2.00 | 61.16±2.56 | 63.16±2.05 | 68.75±2.35 | 68.24±1.66 |
| W4 | 67.14±1.71 | 70.73±2.16 | 71.48±2.70 | 77.16±2.96 | 59.05±1.75 | 64.93±1.88 | 68.29±1.99 | 71.74±1.13 |
| **Afternoon** | | | | | | | | |
| W1 | 74.37±2.03 | 76.38±2.59 | 80.82±1.37 | 82.30±1.61 | 74.29±2.25 | 75.02±3.21 | 79.97±2.37 | 81.84±2.10 |
| W2 | 73.96$^b$±1.95 | 81.74$^a$±1.33 | 81.53$^b$±2.40 | 88.34$^a$±1.94 | 68.57$^b$±1.34 | 77.71$^a$±2.55 | 74.65$^b$±1.74 | 85.79$^a$±2.81 |
| W3 | 73.22$^b$±1.90 | 80.95$^a$±1.68 | 78.86$^b$±1.11 | 85.97$^a$±1.61 | 66.86$^b$±2.15 | 73.94$^a$±1.16 | 72.82$^b$±2.59 | 84.40$^a$±1.90 |
| W4 | 72.86$^b$±2.17 | 80.60$^a$±2.17 | 76.77$^b$±2.67 | 89.76$^a$±3.05 | 66.11$^b$±1.38 | 76.94$^a$±1.72 | 72.34$^b$±1.66 | 84.21$^a$±2.15 |

Means bearing different superscripts (a, b); across rows differ significantly (P≤0.05); between T1 (Control- N=7) and T2 (RPN-N=7).

Table 5. Changes in hematological parameters (Mean±SE) on supplementation of rumen protected niacin in Surti buffaloes.

| Weeks | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) |
|---|---|---|---|---|---|---|---|---|
| | TEC ($10^6$/mm$^3$) | | HCT (%) | | Hb (g/dl) | | PLT ($10^3$/mm$^3$) | |
| W1 | 5.61±0.31 | 6.01±0.15 | 27.46±1.15 | 29.50±1.27 | 9.71±0.54 | 9.67±0.23 | 243.71±13.51 | 258.29±10.13 |
| W4 | 5.21$^b$±0.15 | 6.24$^a$±0.18 | 29.97$^b$±0.85 | 37.03$^a$±1.03 | 8.37$^b$±0.25 | 9.64$^a$±0.12 | 240.43±36.94 | 265.14±23.33 |
| TLC ($10^3$/mm$^3$) | | | LYM% | | MID% | | GRAN% | |
| W1 | 7.24±0.31 | 7.63±0.11 | 43.46±5.80 | 41.76±2.90 | 7.09±0.45 | 8.39±0.42 | 49.46±5.48 | 50.16±2.91 |
| W4 | 6.18±0.25 | 6.37±0.57 | 32.47$^b$±1.76 | 41.80$^a$±1.23 | 7.89±0.34 | 7.20±0.42 | 59.64$^a$±1.72 | 50.97$^b$±1.03 |
| MCV (µm$^3$) | | | MCH (pg) | | MCHC (g/dl) | | MPV (µm$^3$) | |
| W1 | 49.90±3.49 | 49.36±2.78 | 17.37±0.63 | 16.11±0.42 | 35.83±2.76 | 33.24±1.97 | 7.16±0.21 | 6.89±0.12 |
| W4 | 57.73±0.87 | 59.54±0.56 | 16.19±0.67 | 15.54±0.40 | 28.07±1.14 | 26.13±0.73 | 6.96±0.19 | 6.81±0.12 |

Means bearing different superscripts (a, b); across rows differ significantly (P≤0.05); between T1 (Control- N=7) and T2 (RPN-N=7).

Table 6. Changes in blood biochemical parameters (Mean±SE) on supplementation of rumen protected niacin in Surti buffaloes.

| Weeks | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) |
|---|---|---|---|---|---|---|---|---|
| | Glucose (g/dl) | | Total cholesterol (mg/dl) | | Triglyceride (mg/dl) | | NEFA (mmol/L) | |
| W1 | 54.10±1.83 | 52.63±2.44 | 123.33±3.90 | 121.52±4.13 | 26.26±1.42 | 25.40±1.73 | 0.551±0.03 | 0.562±0.02 |
| W4 | 55.42$^b$±1.44 | 68.17$^a$±1.20 | 111.76$^a$±3.31 | 98.23$^b$ ±1.85 | 23.97$^a$±1.44 | 17.26$^b$±0.82 | 0.526$^a$±0.01 | 0.492$^b$±0.01 |
| BHBA (mmol/L) | | | GSH (mg/dl) | | SOD (U/mg of Hb) | | LPO (nm of MDA) | |
| W1 | 0.375±0.02 | 0.386±0.01 | 7.37±0.37 | 7.43±0.36 | 3.13±0.19 | 3.17±0.16 | 3.74±0.18 | 3.87±0.11 |
| W4 | 0.352$^a$±0.02 | 0.302$^b$±0.01 | 7.34$^b$±0.47 | 9.87$^a$±0.09 | 2.74$^b$±0.06 | 3.46$^a$±0.10 | 3.71$^a$±0.09 | 3.38$^b$±0.06 |

Means bearing different superscripts (a, b); across rows differ significantly (P≤0.05); between T1 (Control- N=7) and T2 (RPN-N=7).

Table 7. Changes in milk composition (Mean±SE) on supplementation of rumen protected niacin in Surti buffaloes.

| Weeks | Fat (%) | | Lactose (%) | | SNF (%) | | Density (g/cm$^3$) | | Protein (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) | T1 (Control) | T2 (RPN) |
| W1 | 7.49±0.11 | 7.40±0.09 | 5.14±0.11 | 5.01±0.03 | 8.49±0.14 | 8.51±0.25 | 23.83±0.84 | 25.50±0.24 | 3.27±0.10 | 3.24±0.11 |
| W2 | 7.44±0.12 | 7.50±0.13 | 4.53±0.06 | 4.63±0.06 | 8.41±0.11 | 8.54±0.24 | 26.66±0.72 | 25.49±0.95 | 3.30±0.09 | 3.31±0.10 |
| W3 | 8.04$^b$±0.10 | 8.51$^a$±0.13 | 4.66$^b$±0.06 | 4.95$^a$±0.04 | 8.50$^b$±0.11 | 8.79$^a$±0.10 | 25.00$^b$±0.84 | 27.27$^a$±0.51 | 3.06$^b$±0.07 | 3.22$^a$±0.02 |
| W4 | 7.41$^b$±0.18 | 8.20$^a$±0.09 | 4.51$^b$±0.06 | 4.75$^a$±0.03 | 8.10$^b$±0.10 | 8.61$^a$±0.11 | 23.78$^b$±0.60 | 26.73$^a$±0.55 | 3.02$^b$±0.05 | 3.16$^a$±0.01 |

Means bearing different superscripts (a, b); across rows differ significantly (P≤0.05); between T1 (Control- N=7) and T2 (RPN-N=7).



Table 8. Changes in milk yield (Mean±SE) (Kg) on supplementation of rumen protected niacin in Surti buffaloes.

| Weeks | T1 (Control) | T2 (RPN) |
|---|---|---|
| W1 | 29.37±1.56 | 33.43±2.63 |
| W2 | 33.36±1.40 | 35.77±2.97 |
| W3 | 34.06±1.79 | 38.27±2.67 |
| W4 | 32.60±2.12 | 36.04±2.47 |
| Overall (W1-W4) | 32.35$^b$±0.89 | 35.88$^a$±1.31 |

Means bearing different superscripts (a, b); across rows differ significantly (P≤0.05); between overall yield of T1 (Control- N=28) and T2 (RPN-N=28).

beneficial effects of RPN supplementation are more prominent when there is presence of heat stress. Increase in milk fat has also been reported during niacin supplementation in early lactation in cow (Tienken *et al*., 2015). However, in contrast other studies done by Yuan *et al.* (2012) in transition cows and Zimbelman *et al*. (2010) and Rungruang *et al.* (2014) in heat stress lactating cows found no effect on milk production as well as composition changes.

It was concluded that supplementation of rumen protected niacin in lactating Surti buffaloes increases sweating rate and decreases skin temperature, reduces oxidative stress, and increases milk fat and milk production. It may be recommended to use rumen protected niacin during heat stress period specially during summer as a heat ameliorative measure to prevent the losses of milk production.

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